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THE SPATIAL DISTRIBUTION OF BEHAVIOR UNDER VARYING FREQUENCIES OF TEMPORALLY SCHEDULED WATER DELIVERY

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Two studies evaluated the effects of response-independent water deliveries on the location (on the floor of the experimental chamber) and position (height) of rats' behavior. In both experiments, fixed-time schedules delivered water in two dispensers that were located at opposite ends of the chamber. In Experiment 1, the two schedules provided complementary frequencies of water deliveries while the overall number of deliveries stayed constant. In Experiment 2, one of the schedules delivered water twice as frequently as the other; this proportion was kept constant while the overall density of water deliveries changed systematically. In both experiments, a single position (height) of behavior was dominant. Also, the percentage of time allocated to each dispenser was roughly proportional to the percentage of water deliveries associated with the dispensers. These data and additional considerations support the importance of examining the spatial properties and patterning of behavior.

Key words: fixed-time schedules, time allocation, location of behavior, position of behavior, spatial distribution, rats

Classical and instrumental (or operant) conditioning procedures have traditionally stressed temporal parameters of stimuli and behavior. In classical conditioning, the organism is usually restrained in such a way that spatial parameters of behavior are unimportant; the behavioral measures typically used have been response latency, amplitude, and magnitude (e.g., Beecroft, 1966). In instrumental or operant conditioning procedures, even though the organism is free to move through the experimental environment, the spatial parameters of behavior have also been usually neglected. In instrumental conditioning with runways and mazes, behavior has been mainly analyzed in terms of latency, speed, and choice accuracy (Logan, 1960). In the free-operant situation and in multiple-response devices, similar measures have been used: latency, distributions of interresponse times, response frequency and rate, response proportion, time allocation, and absolute or relative duration of responding (Dunham, 1971; Ferster & Skinner, 1957; Kusmierek & Kowalska, 1998; Shimp, 1969). Studies by Cotton (1953) measuring nonrunning behavior in the runway, Kupalov (1969) and F. J. Silva, Silva, and Pear (1992) examining the geographical distribution of responses, and Notterman and Mintz (1965) studying the dynamic properties of bar pressing exemplify less frequently studied properties of behavior.

Baum and Rachlin (1969), Pear and Rector (1979), and Pear (1985) examined the relation between various time-allocation measures of behavior and different reinforcement schedules. With pigeons, Baum and Rachlin found that the time allocated to two distinct areas of an experimental chamber varied as a function of the ratio of the reinforcement rates provided for standing in these areas by concurrent variable-interval (VI) VI schedules. Pear and Rector similarly found that response propensity, defined as the time spent on a platform in front of the response key, varied consistently with reinforcement frequency, whereas the speed of pecking (measured as the number of key pecks per unit of time spent on the platform) did not. Pear observed the effects of two different VI schedules (VI 15 s and VI 5 min) and extinction of key pecking on the location of the bird in the experimental chamber, and found that the variability and spatial extension of patterns of location increased when frequency of reinforcement decreased.

The studies described above were designed to explore molar measures of behavior that

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could covary with the reinforcement frequency provided by schedules usually requiring discrete responses, such as key pecking and lever pressing. The variations found in time allocation, behavior location, and propensity were interpreted on a par with the effects found using traditional, punctate responses maintained under different ratios of reinforcement frequency. The spatial and time-allocation measures employed were not explicitly considered as samples of a continuous, spatial dimension of behavior that directly participated in the modulation of reinforcement effects.

Schoenfeld and Farmer (1970), however, called attention to the continuous properties of behavior in time and space. The responses in operant reinforcement schedules are only time samples of behavior in a predetermined fixed location (the operandum) within a flow of continuous changes in location, position, and energy expenditure. The operant as a class of molecular, punctate events divides the behavior stream into two complementary discrete segments: responses (R) and nonresponses (NR), the latter sometimes called ''pauses'' or ''interresponse times.'' The size of NR, conceived as the time elapsed without the emission of any R, depends on the rate or density of occurrence of R. Conversely, the rate and density of R are dependent on the duration defining a particular NR (as when interresponse times are selected as the property of behavior to be reinforced: Malott & Cumming, 1964, 1966).

Schoenfeld and Farmer (1970) reported three experiments showing that the probability of reinforcement of NR was an important variable that modulated the effects of the probability of reinforcement for R. These results were interpreted as showing that NR functioned as a context regulating the effects of reinforcement on R, in the sense that the frequency of R was determined not only by the probability of reinforcement of R but also by the probability of reinforcement of NR and the resulting frequency of occurrence of NR. By highlighting the importance of the behavioral stream, these experiments suggest that examining the spatial and dynamic properties of behavior could prove to be illuminating. Schoenfeld and Farmer foresaw the potential advantages of moving to an account of reinforcement effects in terms of continuous changes of behavior in three-dimensional space.

The studies by Schoenfeld and Farmer (1970) called attention to the continuous behavior taking place in the operant chamber and its influence over the operant response (key pecking or lever pressing). Such considerations suggest, at least, the need to explore the possible dependence of the operant response on the spatial and dynamic properties of the continuous behavior taking place in the same situation (Schoenfeld, 1976).

Several variables must be experimentally isolated to establish how spatial dimensions of behavior contribute to the effects of traditional reinforcement schedules defined in terms of punctate responses. The explicit reinforcement of the spatial properties of behavior may be useful to disentangle the effects of variables like the reinforcer contingency, the temporal availability of reinforcement, the number and quality of reinforcers being scheduled, the spatial availability of reinforcers and correlated stimuli, and the patterning and dynamic properties of the responses required to produce or contact reinforcers.

Farmer and Schoenfeld (1966) used a fixed-interval 1-min schedule and presented a neutral stimulus (a change in key illumination) in different temporal positions within the interval. These authors found that, depending upon the temporal placement of the neutral stimulus, response rates preceding, during, and following it reflected the effects of different stimulus functions such as secondary reinforcement, discriminative ''cuing,'' extinction, and chaining. Farmer and Schoenfeld called this procedure of inserting a stimulus at different temporal positions with respect to ongoing behavior the paradigm of the ''intruded'' stimulus. This paradigm may give us information about the spatial segmentation of behavior and how it relates to the traditional, discrete measures typical of the free-operant preparation. Elaborating on the paradigm of the intruding stimulus, a first step should consist of exploring the effects of free stimuli on unrestricted spatial properties of behavior.

We conducted two experiments to evaluate the effects of time-correlated delivery of water in two spatially opposed dispensers on the continuous location and position of the rat's

Table 1

Fixed-time schedule durations for each dipper, number of sessions per phase, number of water deliveries per session, and proportion of water deliveries associated with Dispenser 1 for each phase of Experiment 1.

Phase	Dispenser 1	Dispenser 2	Sessions	Number of water deliveries per session	Proportion of water deliveries in Dispenser 1
1	FT 30 s	Extinction	10	60/0	1.0
2	FT 40 s	FT 120 s	10	45/15	.75
3	FT 60 s	FT 60 s	10	30/30	.50
4	FT 120 s	FT 40 s	10	15/45	.25
5	Extinction	FT 30 s	10	0/60	0

behavior. Water was delivered independently of the rat's behavior to eliminate the explicit spatial and temporal restrictions imposed by contingencies that require a response in a fixed place or location (usually the operandum).

EXPERIMENT 1

The first experiment was designed to explore the effects of two concurrent, complementary fixed-time schedules of water delivery on the time allocation of behavior in various locations and positions (see below for definitions of *location* and *position*). In this study, the proportion of water deliveries in one site relative to the other systematically varied, while the overall frequency of water presentation was kept constant.

Method

Subjects

Four male Wistar albino rats, 5 months old, were used. Each of the rats was experimentally naive and was maintained under a daily schedule of 23 hr of water deprivation. After each experimental session, the rats had free access to water for 30 min. They also had free access to solid food (Purina Chow) in their home cages; the rats' weights ranged between 400 and 450 g. Sessions were conducted 6 days per week, from 11:30 a.m. to 1:30 p.m.

Apparatus

Two MED Associates operant conditioning chambers for rats (ENV-008, 24.3 cm by 29.5 cm by 29.5 cm) were housed in sound-attenuating cubicles. Each chamber had two ENV-201A drop-type liquid dispensers located at the center of the front and rear panels, respectively, 2 cm above the chamber floor. The liquid dispenser provided drops (0.3 cc) of water. Each chamber also included four levers, one 3.5 cm to the left and one 3.5 cm to the right of each liquid dispenser; these four levers were inoperative. Each water dispenser delivered a drop of water; once delivered, water remained available in the receptacle below the dispenser. One 28-V white bulb provided general illumination and was located in the right corner of the rear panel, 27.5 cm above the grid floor. Each liquid dispenser could be illuminated by a 28-V white bulb.

The houselight was on continuously during the session except during water deliveries. Each water delivery was accompanied by the illumination of the relevant dispenser.

The rats' behavior was recorded by a Panasonic RJ36 videocamera. The sound-attenuating cubicles that enclosed the experimental chambers were left open so that the rats' behavior could be tape-recorded from a fixed camera located 1 m in front of each chamber. The experimental room was sound-insulated, the light in the room was off, and no one was present during the experimental sessions. A 486-MED computing system with MED-PC® 2.0 software was used to schedule and record events.

Procedure

The 4 rats were exposed to the same experimental conditions. The experiment consisted of five phases over which two concurrent fixed-time (FT) FT schedules of water delivery varied in duration (Table 1). One FT schedule controlled the operation of one water dispenser, and the other FT schedule controlled the operation of the other dispenser.

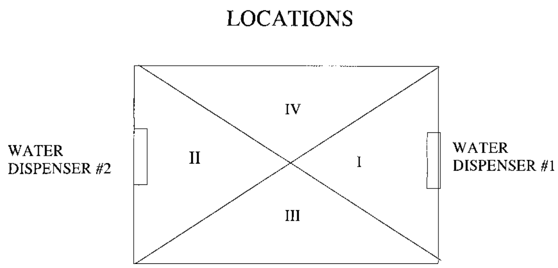

Fig. 1. Definition of behavior locations in the experimental chamber.

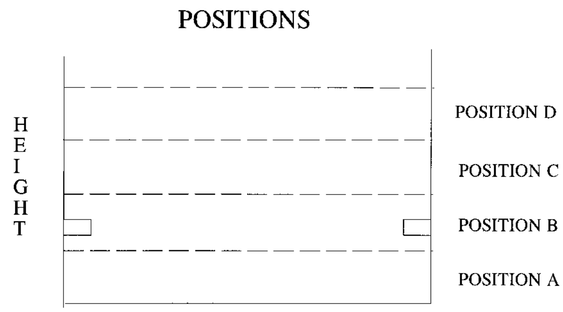

Fig. 2. Definition of behavior positions in the experimental chamber.

The first water delivery was timed from the start of the session; subsequent ones were timed from the previous activation of the dispenser. Each session lasted 30 min, and each experimental phase consisted of 10 sessions.

As can be seen in Table 1, the duration of the FT schedule associated with Dispenser 1 increased systematically across phases (from FT 30 s to extinction), while the length of the FT schedule associated with Dispenser 2 decreased in a complementary fashion, so that the overall number of water deliveries remained constant at 60 per session.

Sessions were videotaped in their entirety. The behavior of each rat was analyzed in terms of the time spent in different locations and positions. *Location* was defined in terms of six categories corresponding to different areas on the floor of the experimental chamber (Figure 1). Two categories corresponded to the rat introducing its head completely into each one of the two water dispensers; four categories corresponded to triangular areas, two of them adjacent to the water dispensers (Areas 1 and 2) and two of them adjacent to the lateral walls of the chamber (Areas 3 and 4). When the rat occupied two areas, the position of its head determined the scoring of the rat's location. *Position* was measured as the height of the rat according to four different categories (Figure 2): (A) the rat lying down, its abdomen in contact with the floor; (B) the rat standing on all four legs; (C) the rat standing on its hindlegs, its body in a curved position; and (D) the rat standing still on its hindlegs or reclining with the anterior legs on the wall of the chamber.

Complete videotapes were coded by four trained observers who transcribed changes in location and position with their time of occurrence for each subject in each of the experimental sessions. The entire behavior of every session was analyzed. Reliability of observational measures was evaluated by an additional observer, who independently coded 20% of the recordings of a random sample of 20% of the sessions in each phase. Reliability was estimated by dividing the number of agreements minus disagreements by the total number of observations. An agreement consisted of two observers coding the same behavior in the same time sample. Average reliability over all phases between observers in this study was 92%.

RESULTS AND DISCUSSION

Figure 3 shows the percentages of time spent in each location × position combination, averaged over the 4 subjects for every phase. (These averaged data are representative of individual results and were computed from individual means for each session.) Position B (the rat standing on all legs) was the most frequent during all experimental phases, with some occurrences of Positions A and C distributed along the various locations. The distribution of behavior location varied as a function of the proportion of water deliveries in each dispenser. During Phase 1, in which all water deliveries occurred in Dispenser 1, most behavior was allocated to this water dispenser and to the adjacent area (Area 1). In

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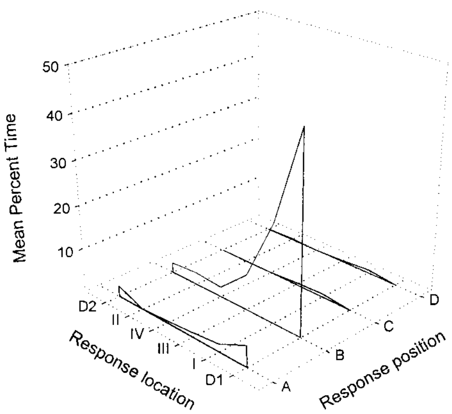
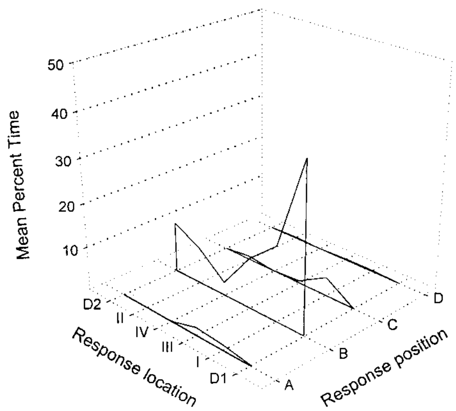
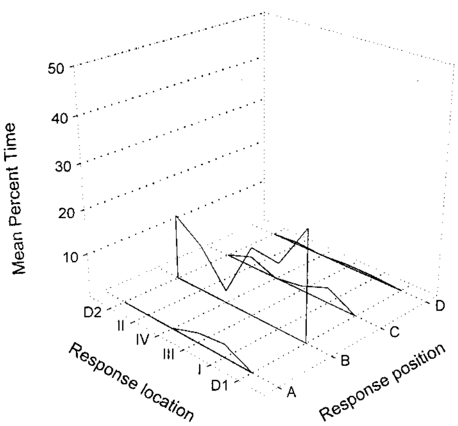
Fig. 3. Percentages of time spent in each location × position combination averaged over the 4 subjects for every phase (Experiment 1). The percentages of water delivery in Dispensers 1 and 2 appear in parentheses.



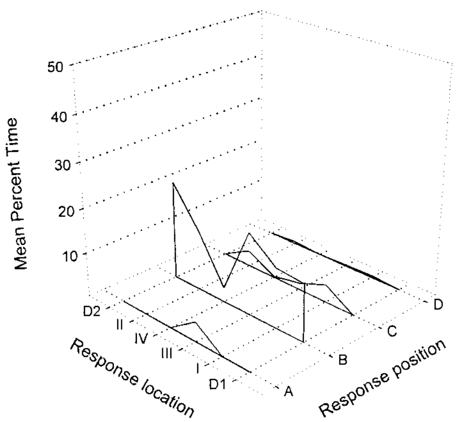
PHASE 1 (100% - 0%)



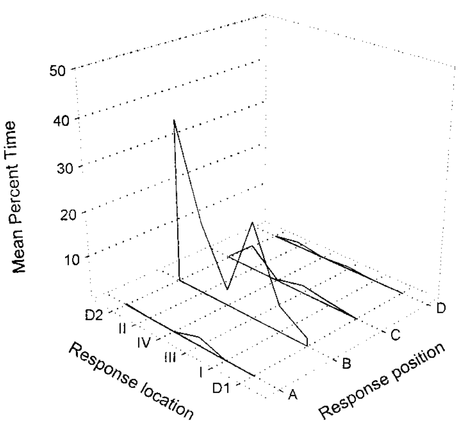
PHASE 2 (75% - 25%)



PHASE 3 (50% - 50%)



PHASE 4 (25% - 75%)



PHASE 5 (0% - 100%)

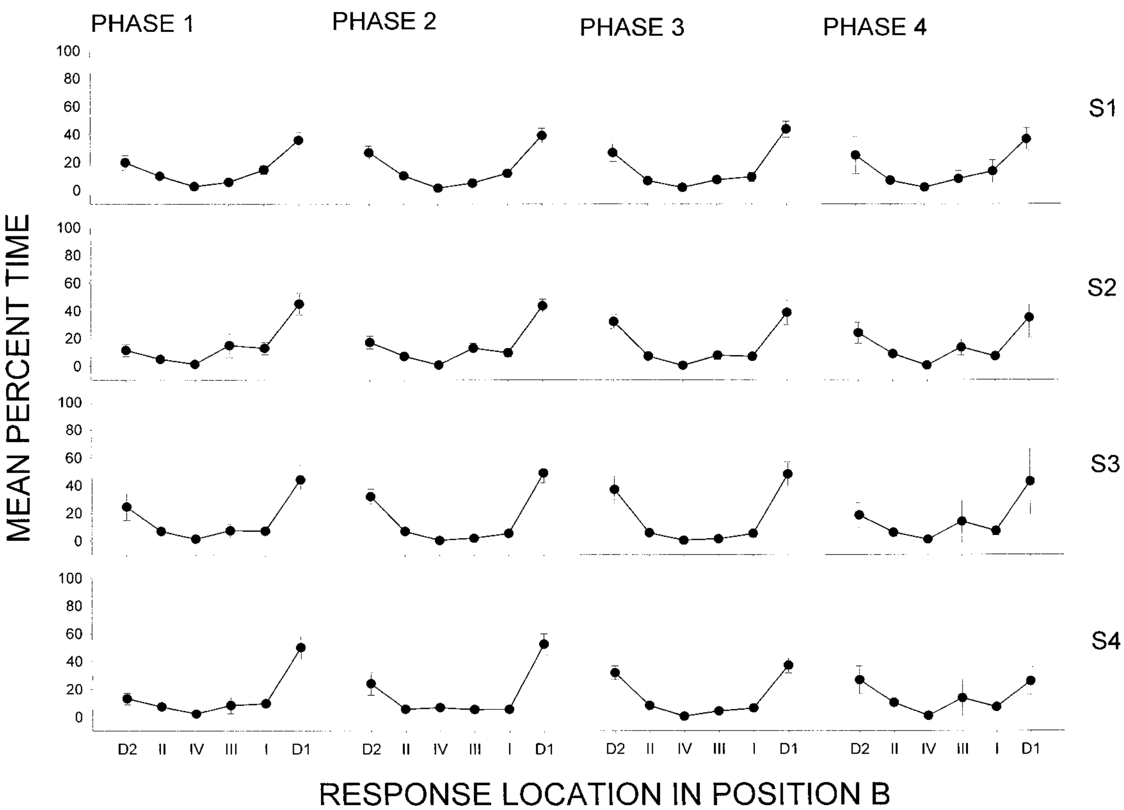


Fig. 4. Individual rats' means and standard deviations of percentage of time in various locations, taking into account only Position B (Experiment 1).

Phase 2, the percentage of time allocated to Dispenser 2 increased while the time allocated to Dispenser 1 decreased; the time allocated to Area 1 decreased, while time spent in Areas 2 and 3 increased. In Phase 3, the time spent in both water dispensers decreased, with more time spent in Dispenser 1 than in Dispenser 2. This decrease coincided with additional increases in the time spent in Areas 1, 2, and 3. In Phase 4, more time was spent in Dispenser 2 than in Dispenser 1, and more time was spent in Area 3 than in Areas 1 and 2. In Phase 5, the time spent in Dispenser 2 increased almost twofold from Phase 4, and the time spent in Dispenser 1 dropped almost to zero. The percentage of time spent in Areas 2 and 3 increased, while the percentage of time spent in Area 1 decreased. Figure 4 shows each rat's means and standard deviations of percentages of time in various locations for only the most frequent position (i.e., Position B). Means and standard deviations have been computed over the 10 sessions of each phase.

Figure 5 shows the percentage of time spent in the two water dispensers and their adjacent areas (Areas 1 and 2) as a function of the associated proportion of water deliveries. The arrows indicate in which order (ascending vs. descending) a dispenser presented the relevant proportions. The time allocations in Areas 1 and 2 increased to approximately 20% with the proportion of water deliveries in their respective dispensers (upper panel). Time spent in a water dispenser increased to approximately 40% with the respective proportion of water delivery (bottom panel). In both cases, the ascending limbs of the obtained functions remained below the descending limbs, suggesting a carryover or a primacy effect of the first phase (in which all water deliveries occurred in Dispenser 1) over the next ones. The percentage of time spent in Dispenser 2 when it was as-

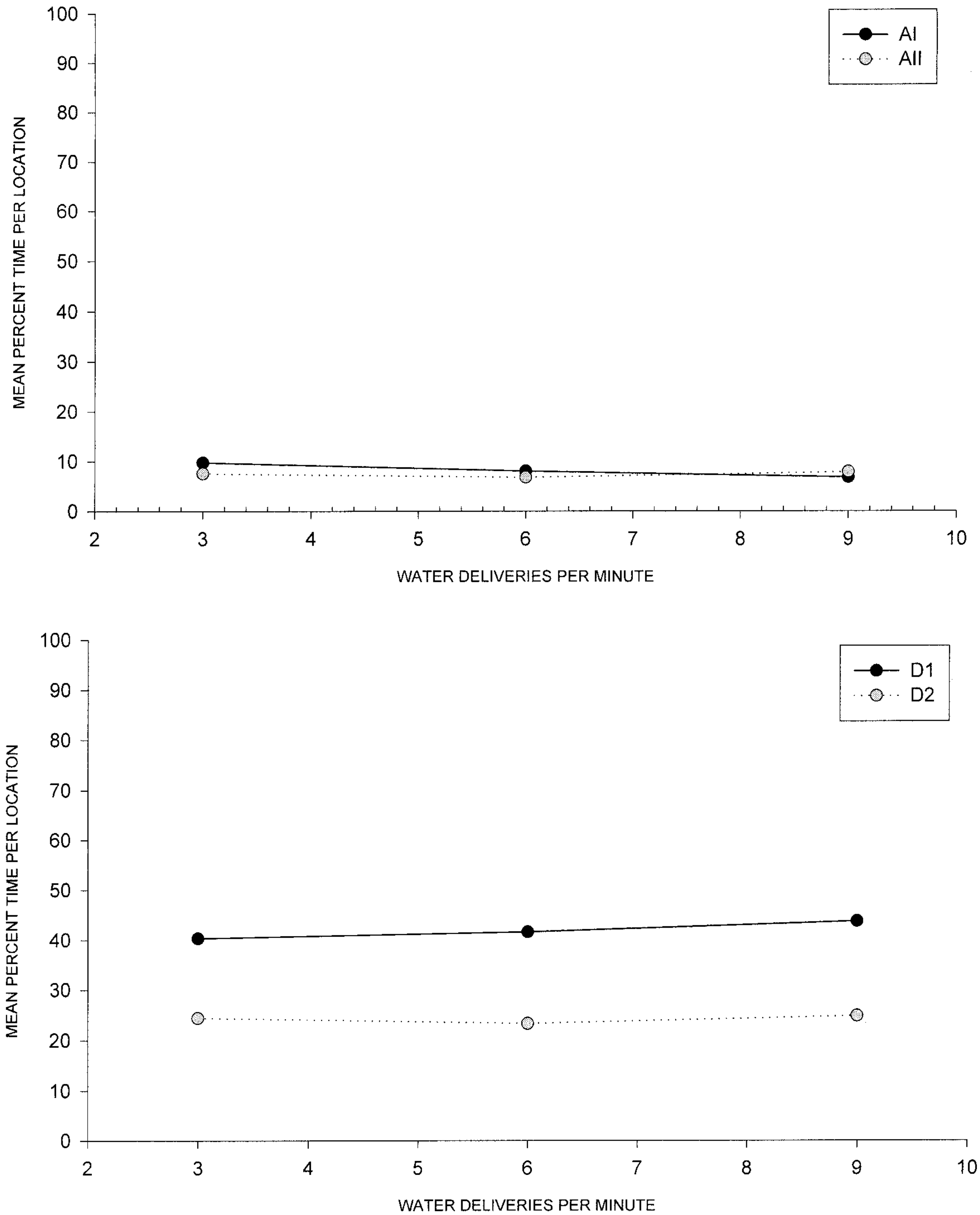


Fig. 5. Percentage of time spent in the two water dispensers and their adjacent areas (Areas 1 and 2) as a function of the associated proportion of water deliveries (Experiment 1). The data are averages over the 4 rats.

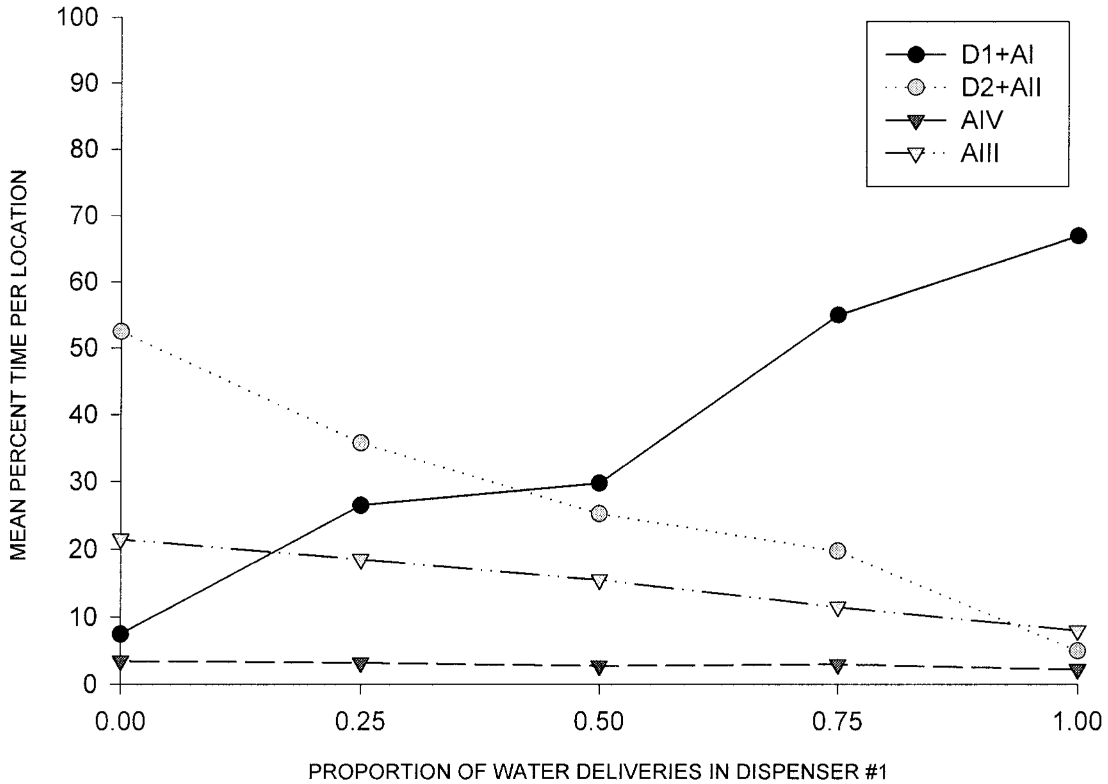


Fig. 6. Percentages of time spent in different areas of the chamber as a function of the proportion of water delivery in Dispenser 1 (Experiment 1). The data are averages over the 4 rats.

sociated with all water deliveries was lower than the percentage of time spent in Dispenser 1 under the same condition. This difference suggests that the rats showed a preference for Dispenser 1, perhaps because it was the first to present all of the water deliveries in a session.

Figure 6 shows the percentages of time spent in different areas of the chamber as a function of the proportion of water delivery in Dispenser 1. The figure includes data for only Position B, which was the dominant response form. The percentages of time spent in Dispenser 1 and its adjacent area (Area 1), and in Dispenser 2 and its adjacent area (Area 2), were inversely related. The time spent in Dispenser 1 and the adjacent area increased with increasing proportions of water deliveries in Dispenser 1, while the time spent in Dispenser 2 and its adjacent area decreased. Consistent with the data in Figure 5, the effects of the changing proportion of water delivery were not symmetrical in both dispensers' areas: The slope of the resulting function for Dispenser 1 was higher than that for Dispenser 2. Similarly, adjacent (Areas 1 and 2) and lateral (Areas 3 and 4) areas were differentially affected by the changing proportion of water delivery in Dispenser 1. More interestingly, the time spent in Area 3 increased as the proportion of water deliveries in Dispenser 1 decreased, whereas the time spent in Area 4 remained close to zero, indicating that each water dispenser regulated different transition patterns among the areas of the experimental chamber.

In summary, the time allocated to the various areas varied systematically as a function of the proportion of water deliveries in each dispenser. The asymmetry of the obtained functions suggests a persistent influence of the first experimental phase, when all water deliveries occurred in Dispenser 1. Finally, observation of the videotapes suggested that the specific effects of changing the proportion of water deliveries on the time allocated to lateral areas (Areas 3 and 4 in Figure 5) might be due to the rat moving across Area

Table 2

Fixed-time schedule durations for each dipper, number of sessions per phase, number of water deliveries per session, and proportion of water deliveries associated with Dispenser 1 for each phase of Experiment 2.

Phase	Dispenser 1	Dispenser 2	Sessions	Number of water deliveries per session	Proportion of water deliveries in Dispenser 1
1	FT 30 s	FT 60 s	10	90 (60/30)	.67
2	FT 15 s	FT 30 s	10	180 (120/60)	.67
3	FT 10 s	FT 20 s	10	270 (180/90)	.67
4	FT 30 s	FT 60 s	10	90 (60/30)	.67

3 from one dispenser to the other, a pattern probably related to the presentation (or lack thereof) of water deliveries in Dispenser 1.

EXPERIMENT 2

The second experiment was designed to explore the effects on location and position of varying the absolute frequency of water delivery while holding constant the proportion of deliveries in each dispenser.

METHOD

Subjects and Apparatus

Four male Wistar albino rats, 4.5 months old, were used. All of the rats were experimentally naive and were maintained under a daily 23-hr schedule of water deprivation. After each experimental session, the rats had free access to water for 30 min. They also had free access to solid food (Purina Chow) in their home cages; the rats' weights ranged from 400 to 450 g. Sessions were conducted 6 days per week, from 12:00 p.m. to 1:00 p.m.

The apparatus was the same as in Experiment 1.

Procedure

Table 2 shows the experimental design of this study. The proportion of water deliveries in Dispenser 1 was held constant at .67 in all experimental phases, and the overall number of water deliveries per 30-min session was set at 90, 180, 270, and 90 across phases. This was accomplished by varying the length of the concurrent FT FT schedules while keeping the length of the FT schedule associated with Dispenser 1 at exactly half the value of the length of the FT schedule associated with Dispenser 2 (see Table 2). An FT schedule delivering water at the end of either 30, 15, 10, or 30 s, depending on the phase, was thus associated with Dispenser 1, and an FT schedule delivered water at the end of either 60, 30, 20, or 60 s across phases for Dispenser 2. Each phase consisted of 10 sessions. Recording and coding procedures were the same as in Experiment 1. The average agreement between observers in this study was 90%.

RESULTS AND DISCUSSION

Figure 7 shows the percentages of time spent on each location × position combination averaged over the 4 subjects for each phase (the averaged data are representative of individual results). As in Experiment 1, Position B (the rat standing on four legs) was the most frequent during all experimental phases, with some occurrences of other positions, mainly Position C, distributed along various locations. The location distribution of behavior seemed to be similar across phases, a constancy that suggests that the overall number (or density) of water deliveries did not affect the distribution of behavior in space. In Phase 4 (replication of Phase 1) the percentage of time allocated to adjacent and lateral areas increased slightly over the percentages in the other phases, and the percentage of time spent in the water dispensers correspondingly decreased. In any event, as Figure 7 shows, most responding was allocated to the water dispensers. Figure 8 shows each rat's means and standard deviations of percentages of time in the most frequent position (i.e., Position B). These means and standard deviations were computed over the 10 sessions of each phase.

Figure 9 shows the percentage of time per position in both water dispensers and their adjacent areas as a function of the overall frequency of water deliveries in both dispensers

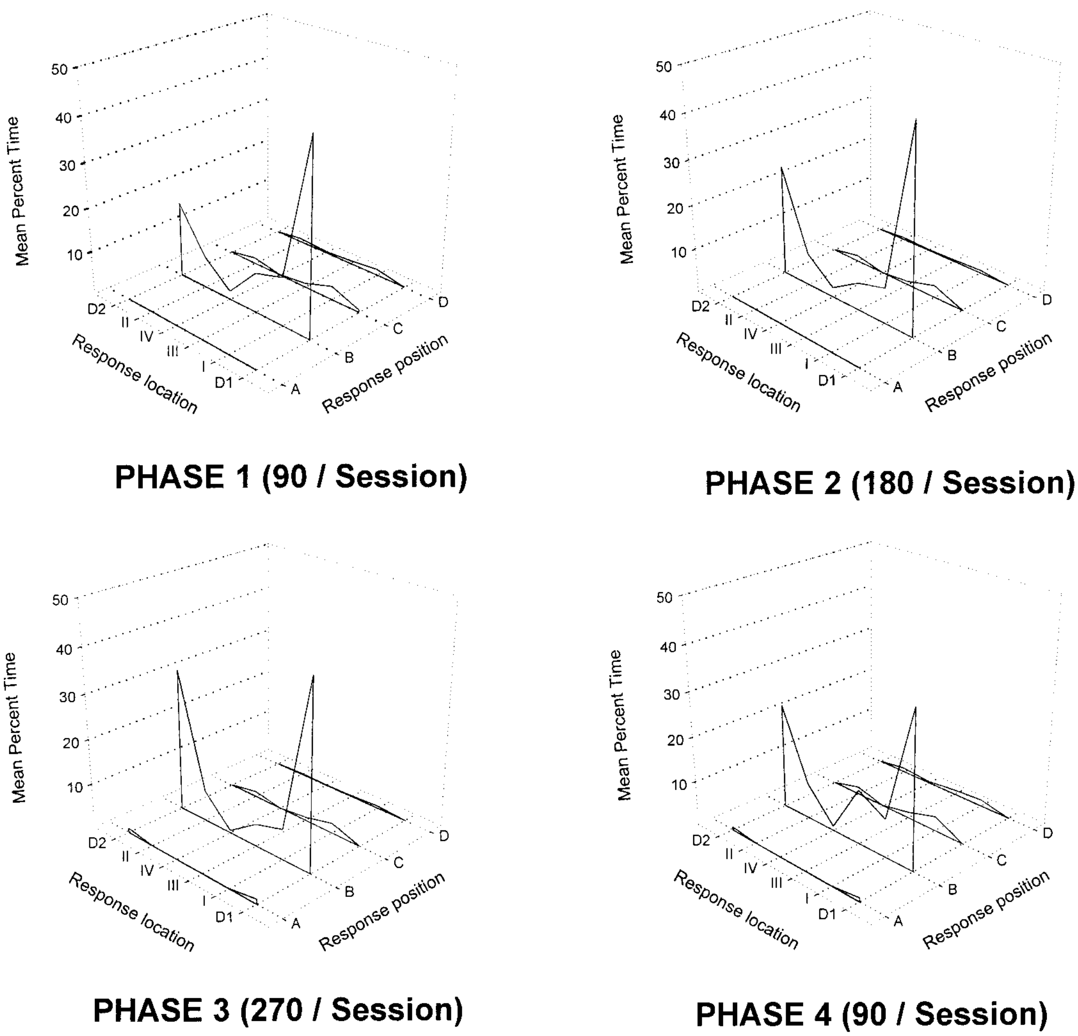


Fig. 7. Percentages of time spent in each location × position combination averaged over the 4 subjects for every phase (Experiment 2). The overall number of water deliveries per session in both dispensers appears in parentheses.

(the data of Phases 1 and 4 are averaged together). The percentages of time spent in Areas 1 and 2 were virtually identical, showing an overlapping flat function (upper panel). Time spent in both dispensers remained constant across the different frequencies of water delivery, the time spent in Dispenser 1 being about twice as high as the time spent in Dispenser 2 (bottom panel).

Figure 10 shows the time spent in each water dispenser, in its adjacent area, and in Areas 3 and 4 as a function of the overall frequency of water deliveries. The time spent in Dispenser 1 plus Area 1 remained constant at about 50% to 55%, whereas the time spent in Dispenser 2 plus Area 2 tended to increase with increases in the overall frequency of water delivery. Time spent in Areas 3 and 4 tended to decrease with increases in the overall frequency of water delivery.

In summary, the relative time spent in each water dispenser seemed to be determined by the proportion of water deliveries in these dispensers, independent of the overall frequency of water deliveries. Time spent in Areas 1 and 2, however, seemed to be independent of overall and relative frequencies of water delivery (recall, however, that times

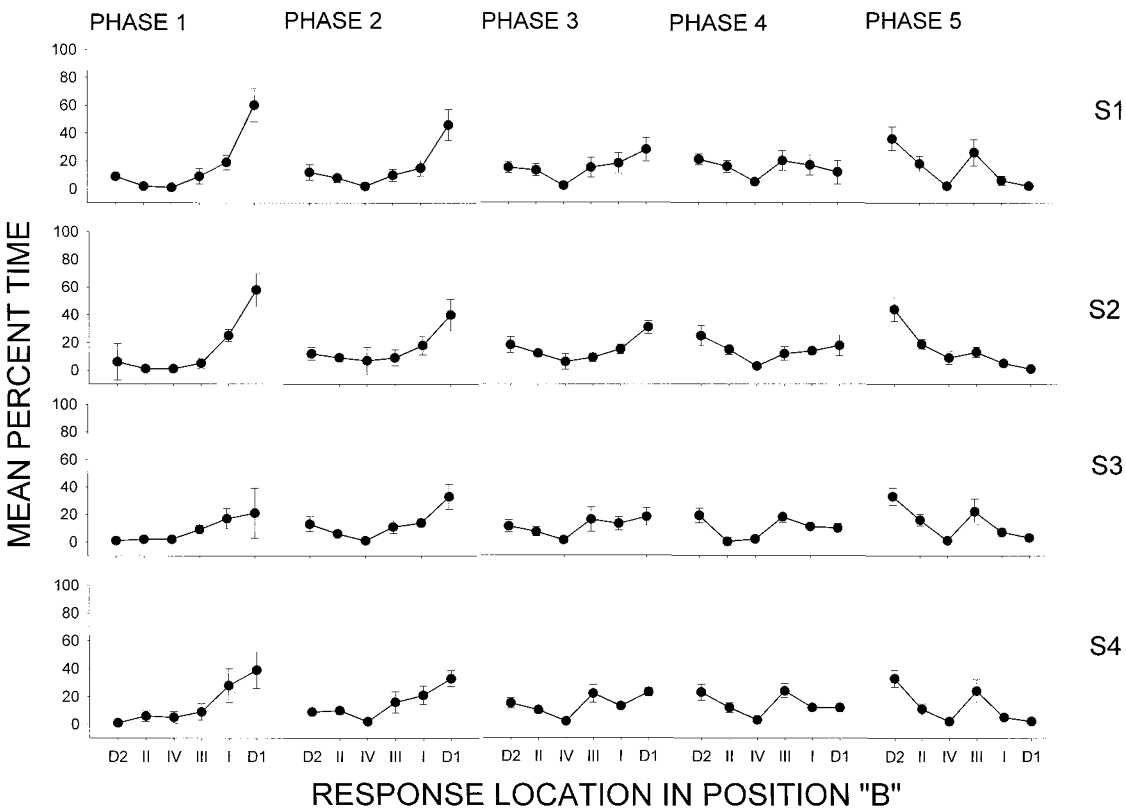


Fig. 8. Individual rats' means and standard deviations of percentages of time in various locations, taking into account only position B (Experiment 2).

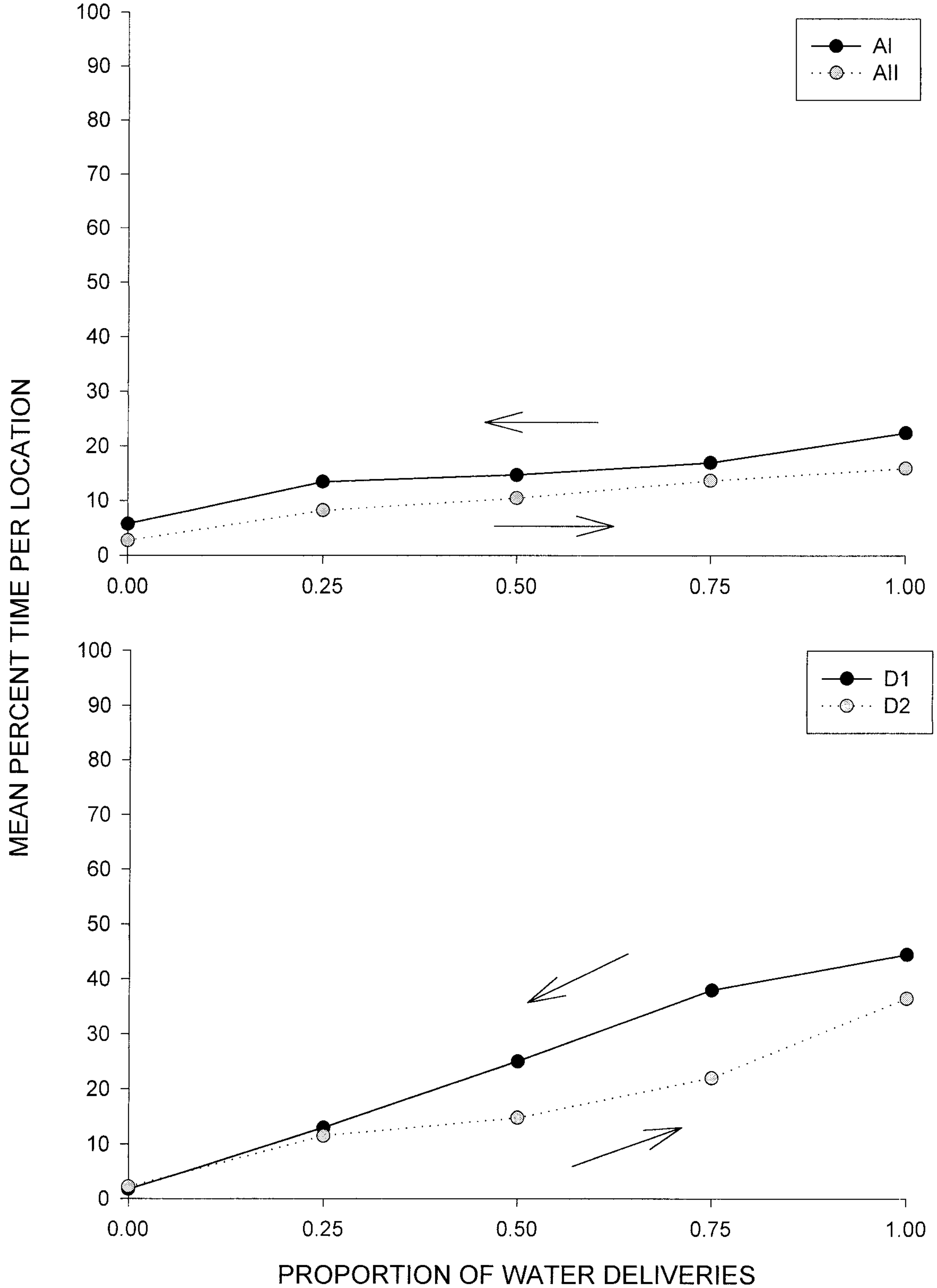
spent in Areas 1 and 2 did not include times spent with the head in the dipper).

GENERAL DISCUSSION

The results of the two experiments suggest a strong effect of the relative frequency of water deliveries on the temporal distribution of the spatial properties of behavior, whether the relative frequency of water deliveries changed across phases (Experiment 1) or remained constant (Experiment 2). In both experiments, the relative time spent in Dispensers 1 and 2 tended to match the proportion of water deliveries in these dispensers (cf. Baum & Rachlin, 1969).

The time spent in Areas 1 and 2, adjacent to the water dispensers, however, did not increase with water-delivery proportions at the same rate as the time spent in the water dispensers themselves. The large proportion of time spent in both dispensers, relative to the time spent in the adjacent areas, occurred in spite of the fact that water delivery was correlated with the interruption of the houselight and the illumination of the dispenser. Thus, the large proportion of time spent in the dispensers cannot be attributed to the absence of discriminable cues that signaled the time of water delivery. In Experiment 1, the time allocated to Areas 1 and 2 was about 20%, compared to approximately 40% for the average time allocated to water dispensers. In Experiment 2, the time allocated to Area 1 remained roughly constant, as was the case with the time allocated to Area 2.

More unexpectedly, in Experiment 1, the time allocated to Areas 3 and 4 (lateral areas) increased systematically with increases in the proportion of water deliveries in Dispenser 2. It seems that the rats developed a pattern that initially consisted of staying in Dispenser 1 and its adjacent area (Area 1). This first contact with water presentation and the concurrent availability of another water dispenser or water presentations in subsequent phases may



AI
AII
D1
D2
100
90
80
70
60
50
40
30
20
10
0
0.00
0.25
0.50
0.75
1.00
MEAN PERCENT TIME PER LOCATION
PROPORTION OF WATER DELIVERIES

have determined the dominance of a particular position or topography (B) during all experimental conditions. With increases in the frequency of water deliveries in Dispenser 2 (and the complementary decrease in Dispenser 1), the rats tended to switch between dispensers more frequently (data not presented), but with a higher sampling proportion of Dispenser 1, which was the first to provide water in this experiment. The resulting switching behavior subtracted some time of occupation from the area adjacent to Dispenser 2 (Area 2).

In Experiment 2, the rats obtained water from both dispensers even during the first session. With increasing frequencies, rats tended to spend more time in each water dispenser and its adjacent area and less time in the lateral zones, although, in some cases, as in Experiment 1, occupation of Area 3 tended to be similar to or higher than that of Area 2 (adjacent to the water dispenser with the lower relative frequency of water).

The results of these experiments do not coincide with the findings by Pear and Rector (1979) with pigeons that propensity, defined as the time allocated to the areas adjacent to food dispensers, seems to be sensitive to the frequency of food delivery, in contrast to behavior directly bound to producing (or finding) and consuming food. In Pear and Rector's study, propensity included the behavior allocated to the area adjacent to food dispensers as well as the time spent key pecking. When water consumption, the terminal response in our study, is analyzed separately from the behavior allocated to the areas adjacent to the water dispensers, adjacent behavior does not seem to be sensitive to changes in the frequency of water deliveries. In our studies, licking was not directly measured, but it is unlikely that the rat was licking a single drop of water for 30, 60, or 90 s. It is plausible that staying in the dispenser area did not involve licking most of the time. If staying with the head inside the dispenser were considered similar to key pecking, then our results would be similar to those of Pear and Rector, but it is difficult to equate a response with explicit operant properties (such as key pecking) with a component of a consummatory response controlled by water delivered independently of responding. Similarly, the data of Experiment 2 do not coincide with the findings by Pear (1985) that the variability and extension of position patterns increase with decreasing frequency of reinforcement, although the interval values sampled in our study were closer to one another than those used by Pear.

Other studies suggest that consummatory or instrumental (operant) responding and other behavior that takes place during the interreinforcement interval may show different temporal and spatial patterns as a function of the schedule used. Because these studies used chamber sizes larger than that in our studies and nonconcurrent schedules, their findings do not necessarily replicate the results of our experiments. F. J. Silva and Pear (1995), using FT and fixed-interval food schedules, found that behavior was less stereotyped during response-independent than during response-dependent food delivery, and that stereotypy increased after food delivery, whereas it decreased as food-delivery time approached. K. M. Silva and Timberlake (1998) measured various categories of behavior such as feeder nosing, rearing, paw grooming, feeder-directed behavior, and locomotion remote from the feeder during an FT schedule. They found that responses near the feeder peaked in frequency before and after food presentation, whereas locomotion remote from the feeder peaked at the middle of the interfood interval. Nevertheless, feeder nosing and remote locomotion peaked at times proportional to the interfood interval length, whereas the other types of behavior (rearing, feeder-directed responding, and paw grooming) peaked at a fixed time after food, regardless of the interfood-interval length.

When general activity is measured in addition to an operant response, various results also suggest that different variables affect the two behavior classes. Allan and Matthews (1991, 1992), using an FT schedule with a setback (i.e., delay-producing) contingency on

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Fig. 9. Percentage of time per position in both water dispensers and their adjacent areas as a function of the overall frequency of water deliveries in both dispensers in Experiment 2. The data are averages over the 4 rats.

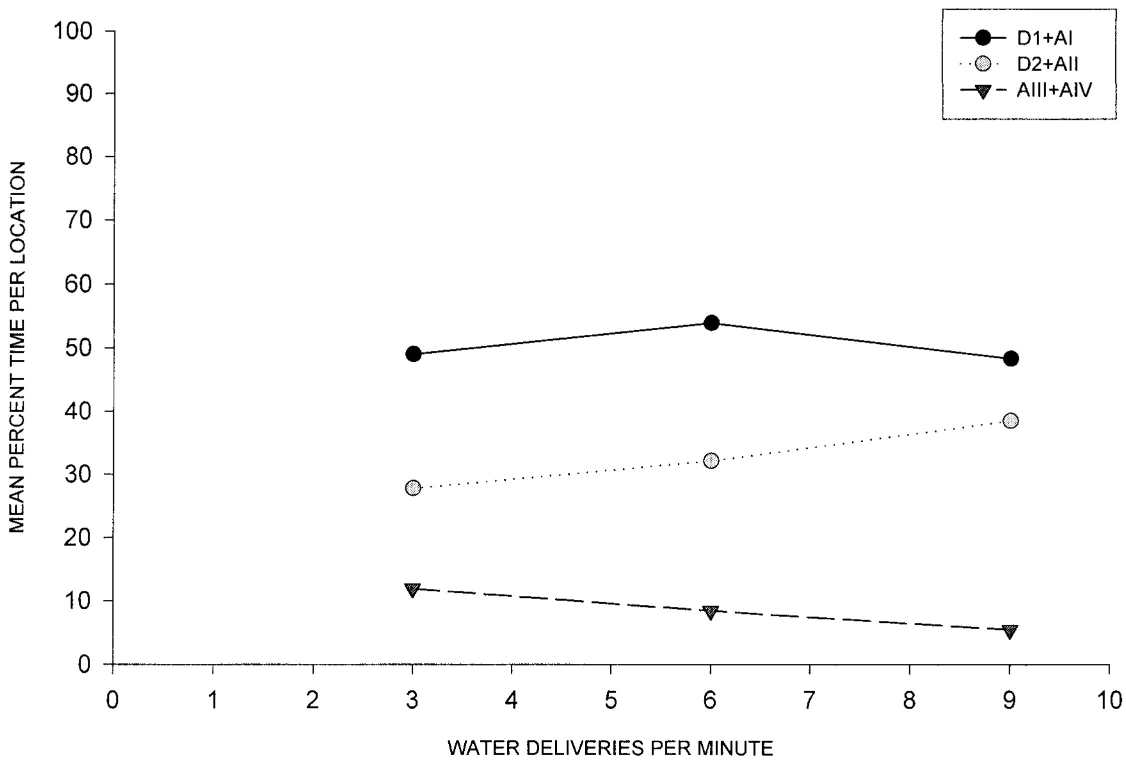

Fig. 10. Percentage of time spent in each water dispenser and the four areas of the chamber as a function of the overall frequency of water deliveries in both dispensers in Experiment 2. The data are averages over the 4 rats.

locomotion, found that decreases in interim induced general activity were not systematically related to increases in rate of autoshaped key pecking.

These contrasting results may be due to differences between our experiments and previous ones that used spatial measures of behavior. For instance, the species used as experimental subjects may be crucial, because the standard operant responses of rats and pigeons differ in many mechanical and biological features (Schwartz, 1977); the role played by locomotion and movement patterns may also differ among species. Staddon and Simmelhag (1971) and Staddon and Ayres (1975), for example, found different patterns and types of behavior when they studied rats and pigeons under an FT schedule of food presentation. Some caution should be exercised when comparing results from studies with rats and pigeons under supposedly equivalent conditions.

Explicit differences in scheduling should also be taken into account. First, our experiments scheduled concurrent water deliveries, whereas Pear and Rector (1979) and Pear (1985) used simple schedules. Second, in the present studies, water was presented independent of any explicit response requirement, in contrast to other experiments (Baum & Rachlin, 1969; Pear, 1985; Pear & Rector, 1979) in which reinforcement was contingent on the location of the organism or a specific operant response. Although no response was required for water presentation in our studies, some features of the consummatory response may involve implicit contingencies (Ribes, 1997). In some cases of water consumption under FT schedules (compared to pellet consumption), the rat has to be near the dispenser before consuming the drop. The temporal availability of water in the dispenser may be another variable that modulates the spatial distribution of behavior, reminiscent of the time-restricted availability of the grain typically used as a reinforcer with pigeons and the unrestricted availability of the pellets usually provided to rats. The height and location of the food magazine or water dispenser may also determine spatial properties of behavior that in turn affect the rate and patterning of the operant response (Wasserman & Molina, 1969). The use of a larger-than-standard experimental space may also affect the patterning of behavior (Ribes & Chávez, 1988; Skuban & Richardson, 1975). Other parameters to consider are the nature of the correlations and temporal distributions of stimuli, including reinforcers.

In any event, extensive research is needed to explore the different variables that are involved in the spatial patterning of behavior and its relation with the structural properties of schedule-controlled performance. Moving toward a parametric and molar analysis that includes spatial measures and contingencies may be a better way to understand many characteristics of the punctate, molecular, discontinuous data upon which most of present knowledge is based.

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